Radiative Forcing by Well-mixed Greenhouse Gases: Comparison of IPCC Models

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11/2/2005, Hampton, VA

Goals of this Study

Radiative Transfer Model Intercomparison Project (RTMIP)

- Compare forcing by well-mixed GHGs from:
  - GCMs participating in the IPCC AR4
  - Line-by-line (LBL) codes: benchmarks
- Determine accuracy of GCM codes under idealized conditions.
- Types of forcing considered:
  - Present-day – preindustrial changes in WMGHGs
  - $2\times CO_2 - 1\times CO_2$ and $4\times CO_2 - 1\times CO_2$
  - Combinations of increased CH_4, N_2O, and CFCs
  - Feedbacks from increased H_2O

Design of the Intercomparison

- Comparison of instantaneous forcing (not flux):
  - Stratospheric adjustment is not included.
  - Instantaneous forcings are included in WGCM protocol for IPCC simulations.
- Calculations are for clear-sky conditions.
  - We use a climatological mid-latitude summer profile.
  - Including clouds would complicate the intercomparisons.
- Radiative effects of constituents:
  - Absorption by H_2O, O_3, and WMGHGs
  - Rayleigh scattering
  - Self and foreign line broadening

Participating AOGCM and LBL groups

AOGCM Groups

Originating group[a]	Country	Model
BCCR	Norway	BCCR-BCM2.0
CCCma	Canada	CGCM3.1(T47/T63)
CCSR/NIES/FRCGC	Japan	MIROC3.2(medres/hires)
CNRM	France	CNRM-CM3
GFDL	USA	GFDL-CM2.0/2.1
GISS	USA	GISS-EH/ER
INM	Russia	INM-CM3.0
IPSL	France	IPSL-CM4
LASG/IAP	China	FGOALS-g1.0
MIUB/METRI/KMA	Germany/Korea	ECHO-G
MPIfM	Germany	ECHAM5/MPI-OM
MRI	Japan	MRI-CGCM2.3.2
NCAR	USA	CCSM3
NCAR	USA	PCM
UKMO	UK	HadCM3
UKMO	UK	HadGEM1

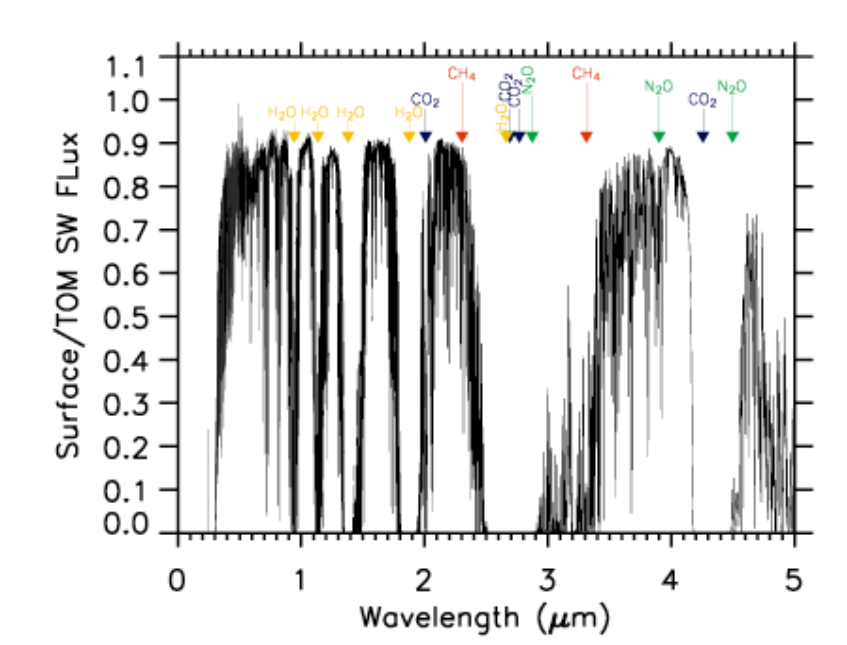
LBL Modelers

Originating group[a]	Country	Model	Reference
GFDL	USA	GFDL LBL	*Schwarzkopf and Fels* [1985]
GISS	USA	LBL3	–
ICSTM	UK	GENLN2	*Edwards* [1992]; *Zhong et al.* [2001]
LaRC	USA	MRTA	*Kratz and Rose* [1999]
UR	UK	RFM	*Dudhia* [1997]; *Stamnes et al.* [1988]

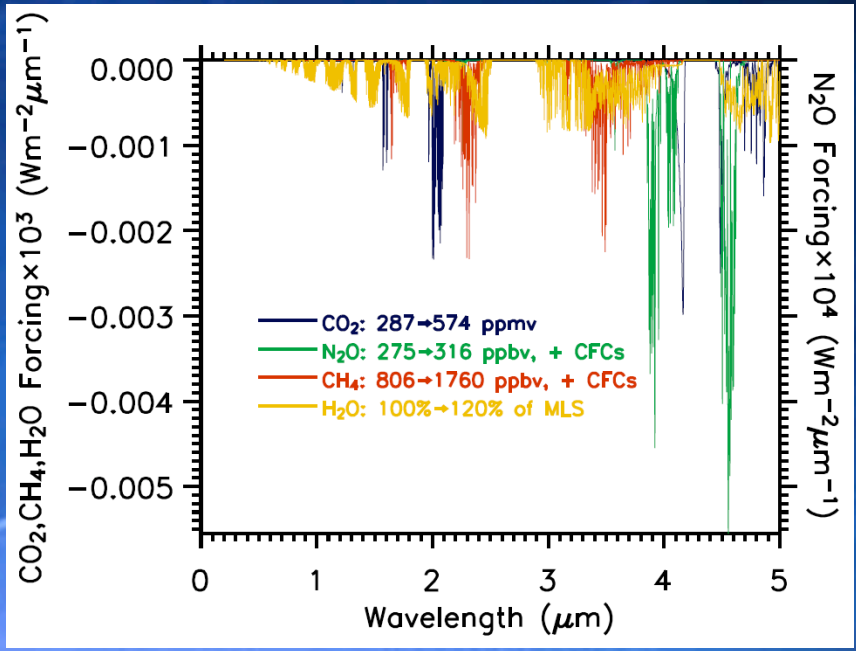
- There are 16 groups submitting simulations from 23 AOGCMs to the IPCC AR4.
- RTMIP includes 14 of these groups and 20 of the AOGCMs.

Shortwave radiative forcing at the surface

Transmission



Forcing



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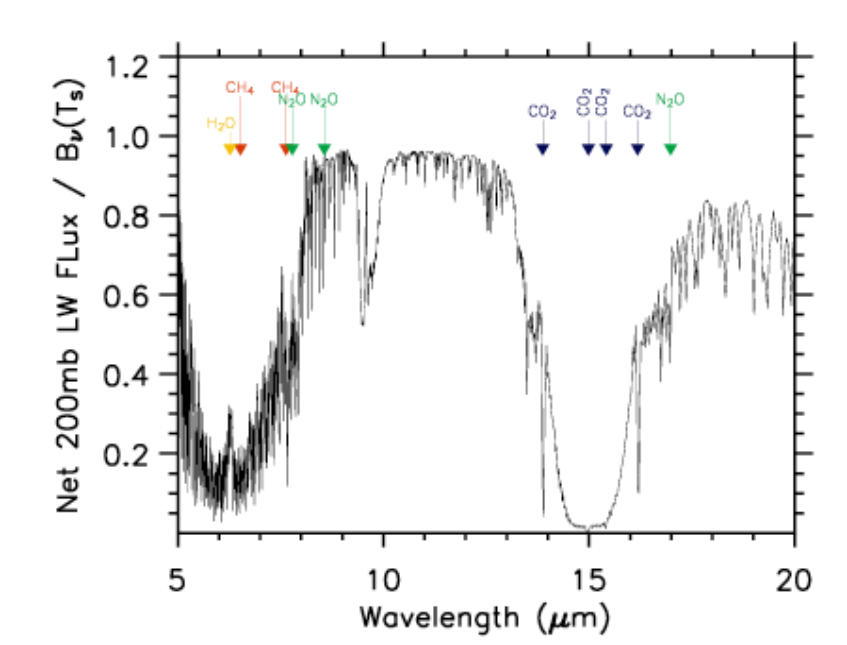
Longwave radiative forcing at 200 mb

Transmission



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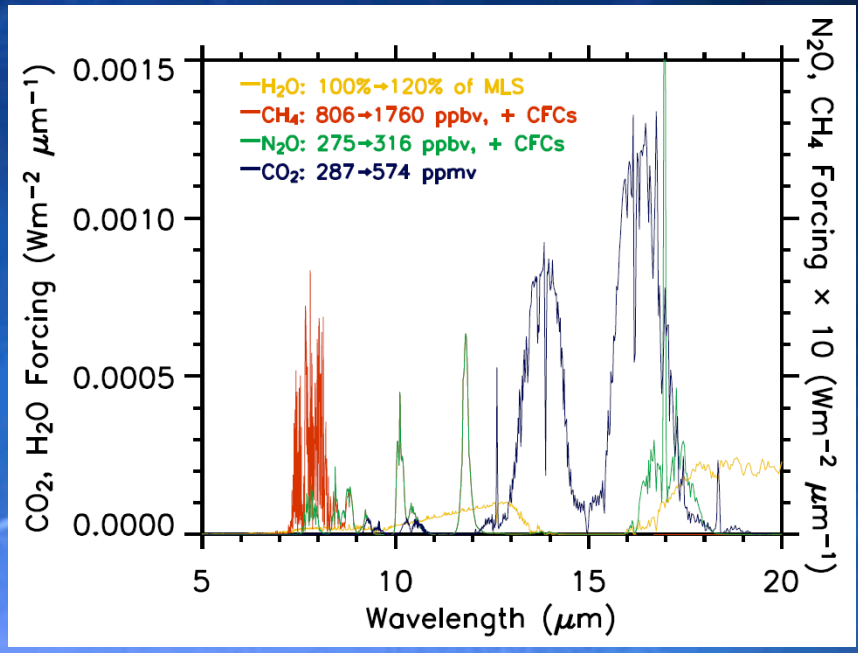
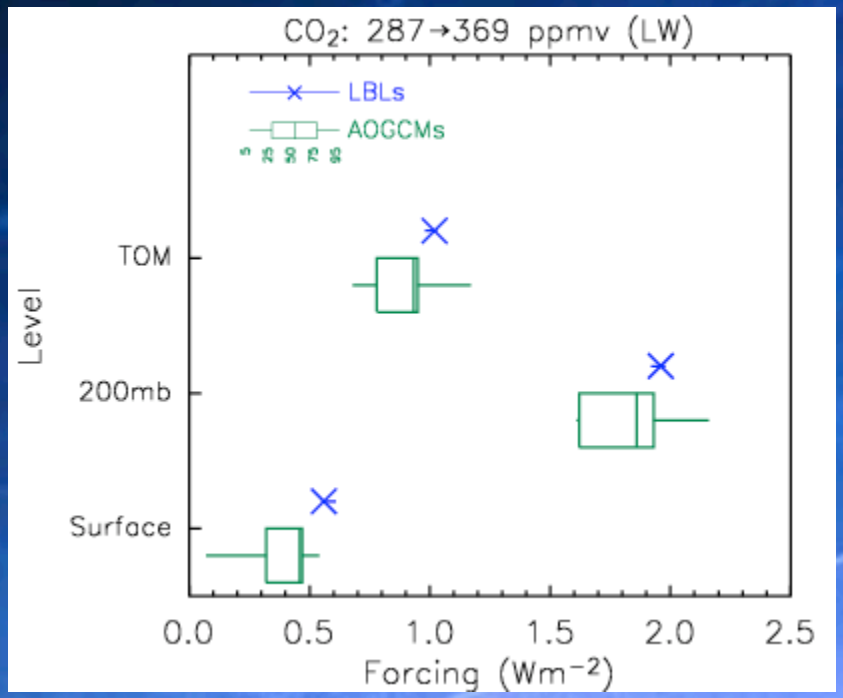


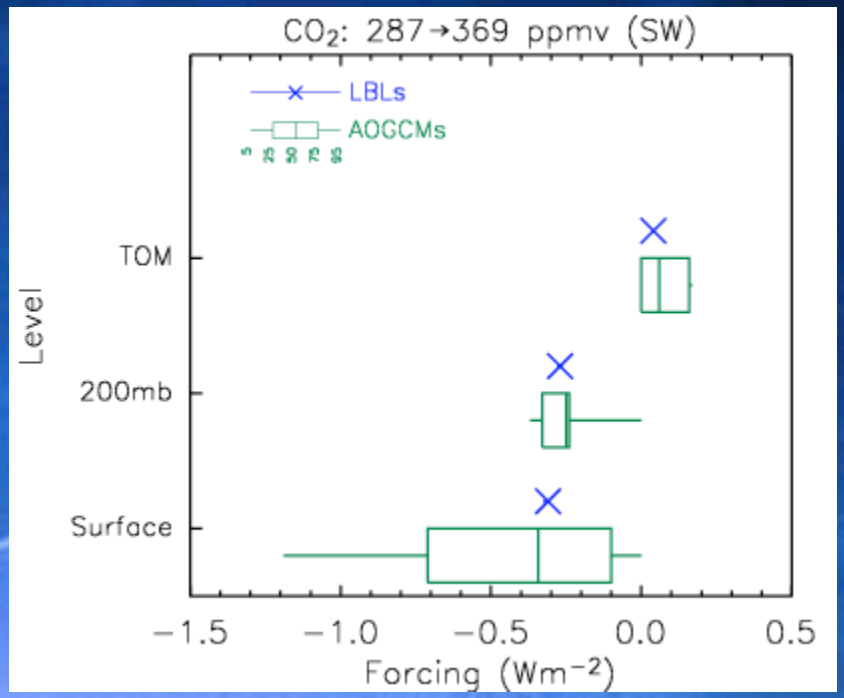
Collins et al, 2005

Forcing by historical increases in CO_2

Longwave



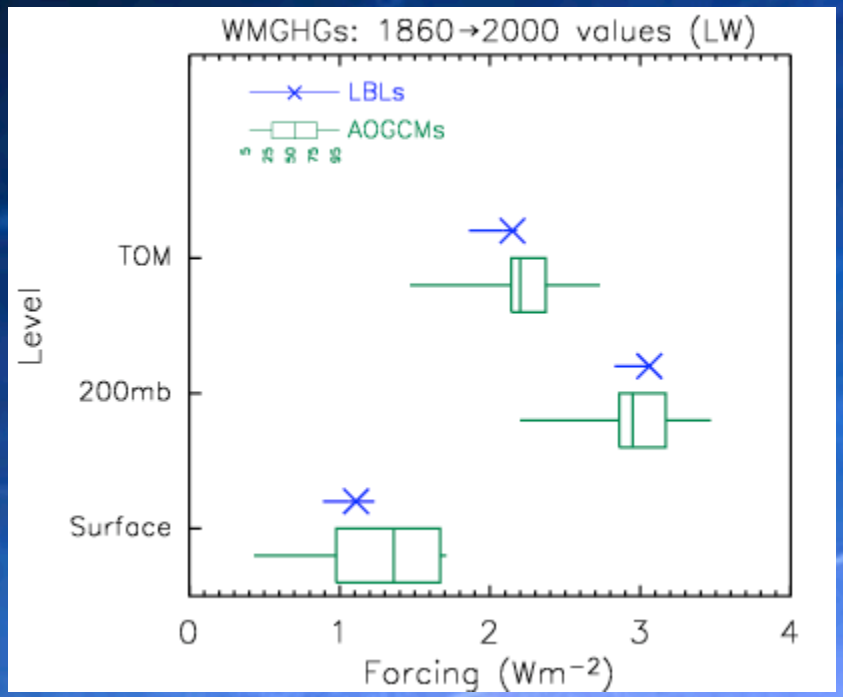
Shortwave



Collins et al, 2005

Forcing by historical increase in WMGHGs

Longwave



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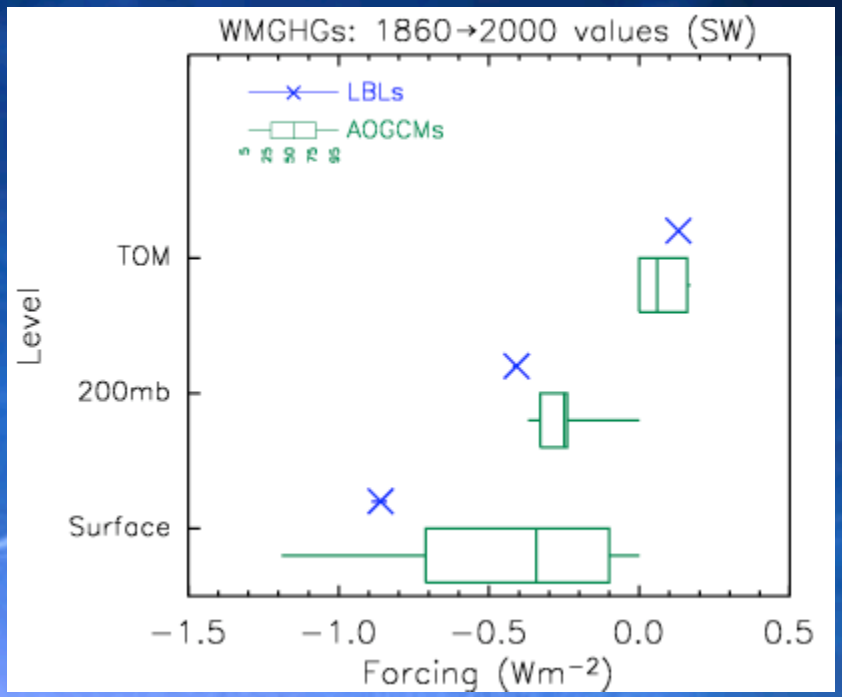
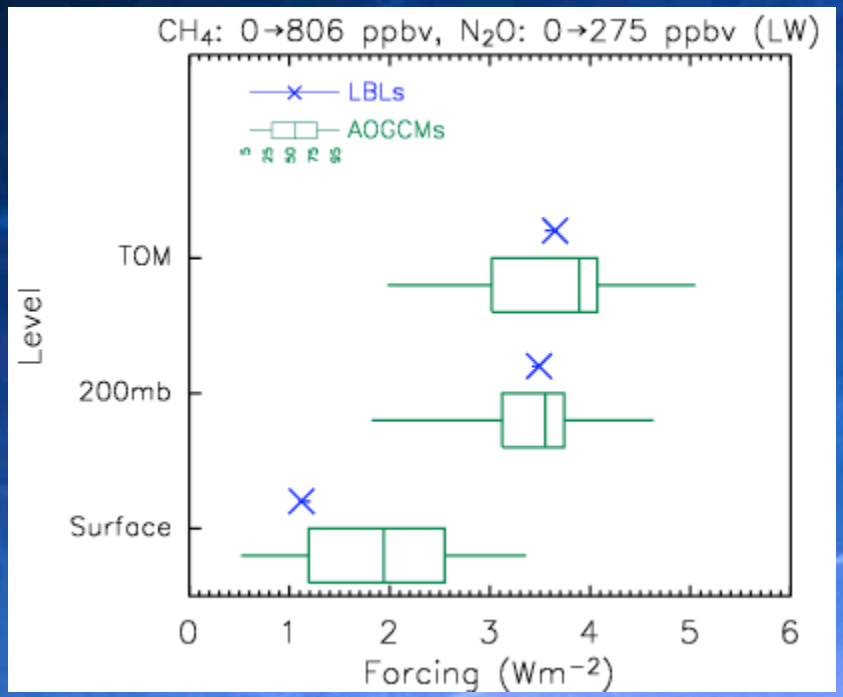


Collins et al, 2005

Forcing by methane and nitrous oxide

Longwave



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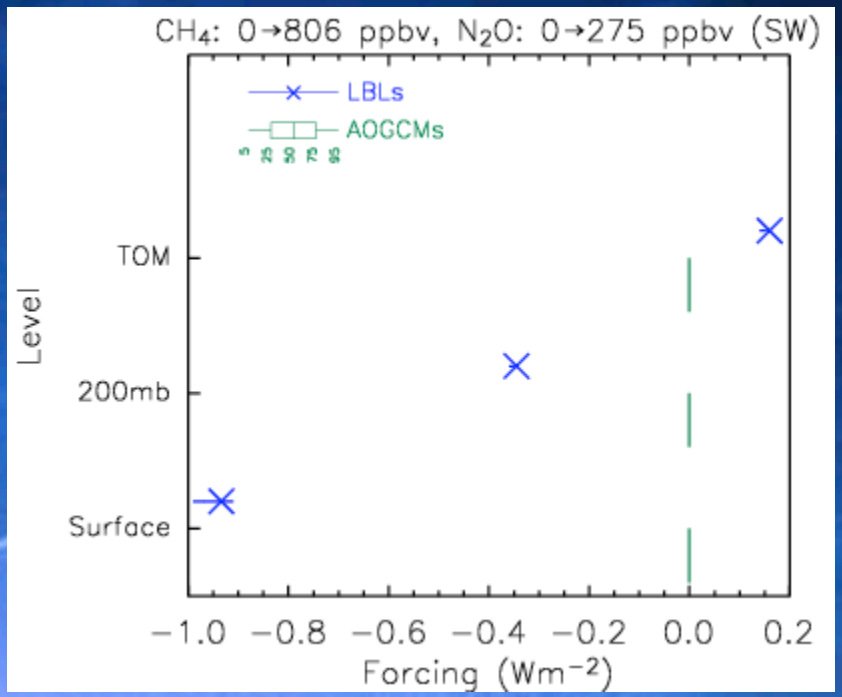
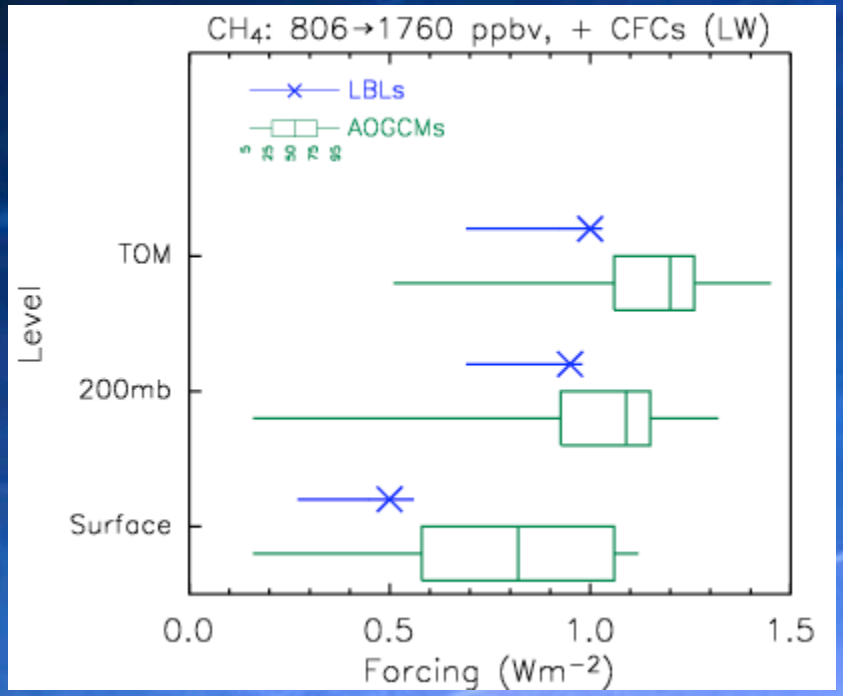


Collins et al, 2005

Forcing by methane + CFCs

Longwave



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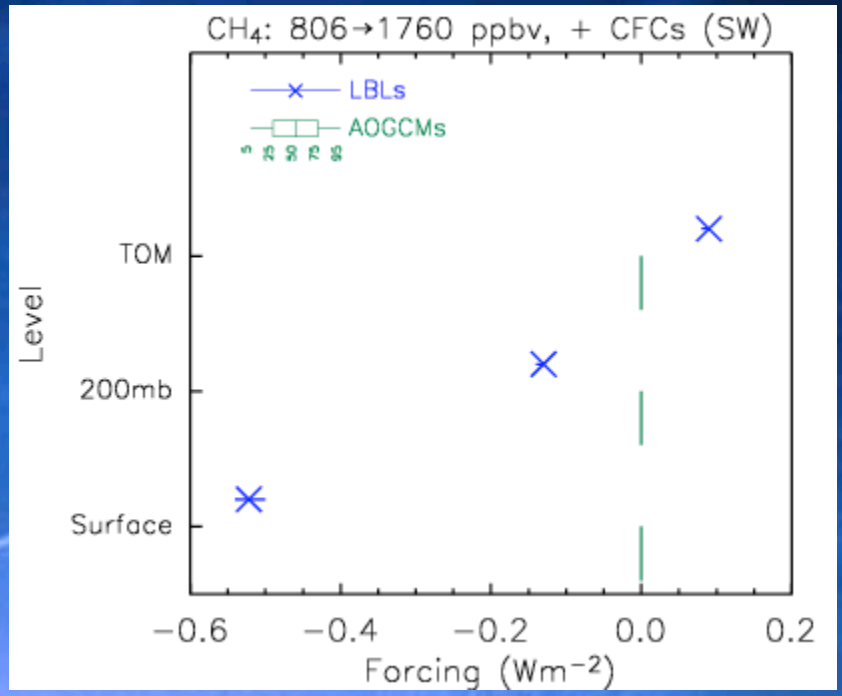
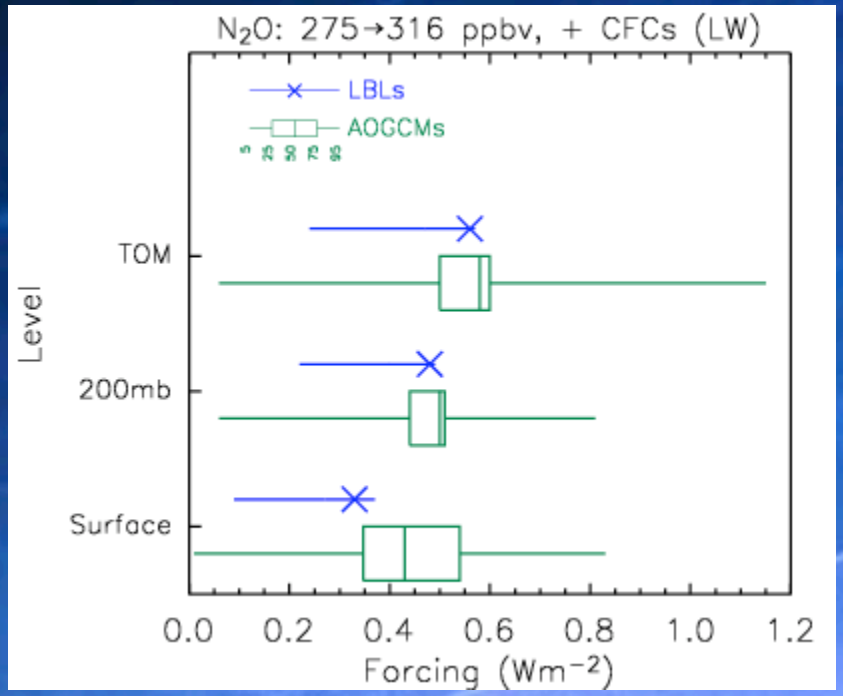


Collins et al, 2005

Forcing by nitrous oxide + CFCs

Longwave



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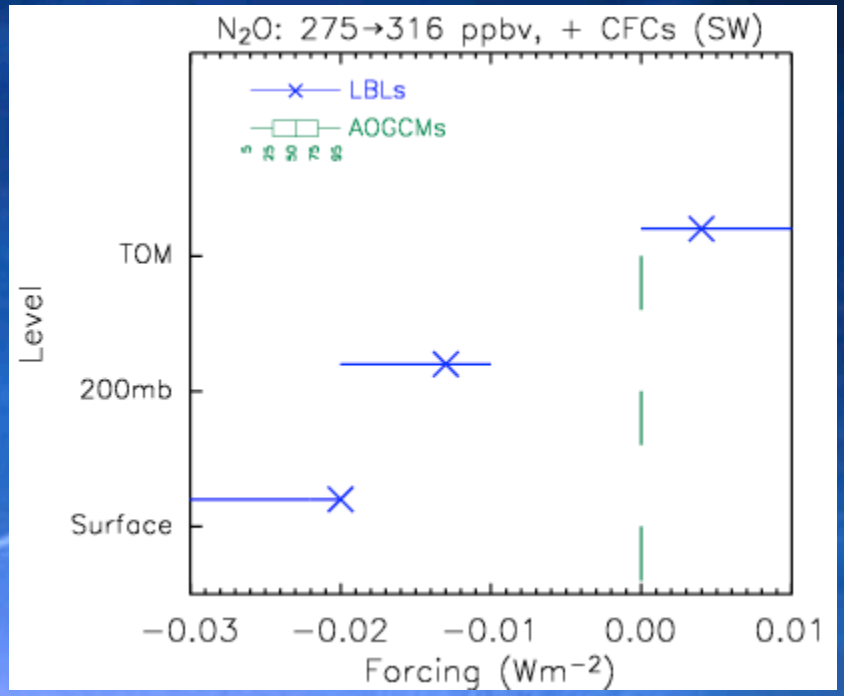

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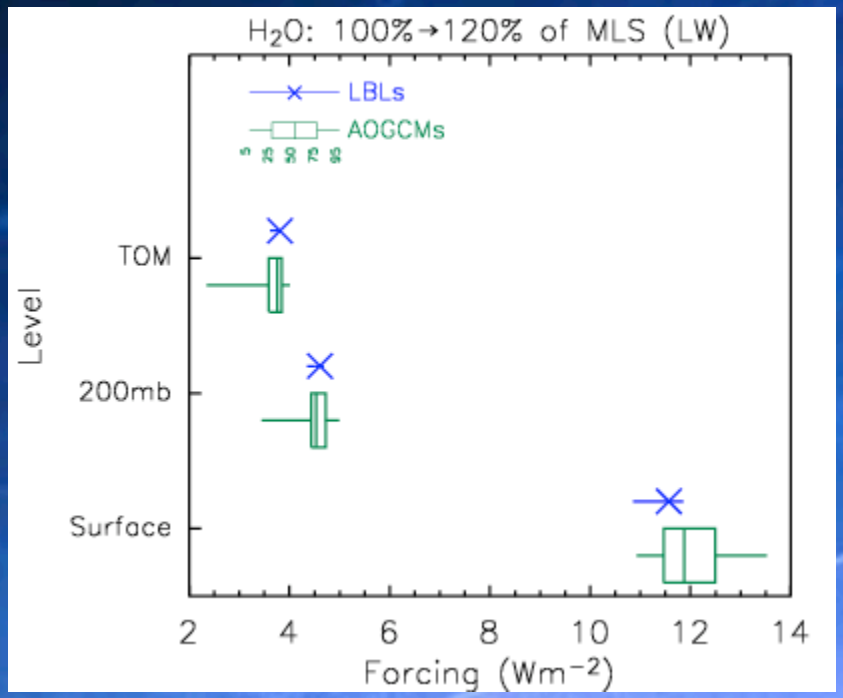
Forcing by water vapor feedback

Longwave



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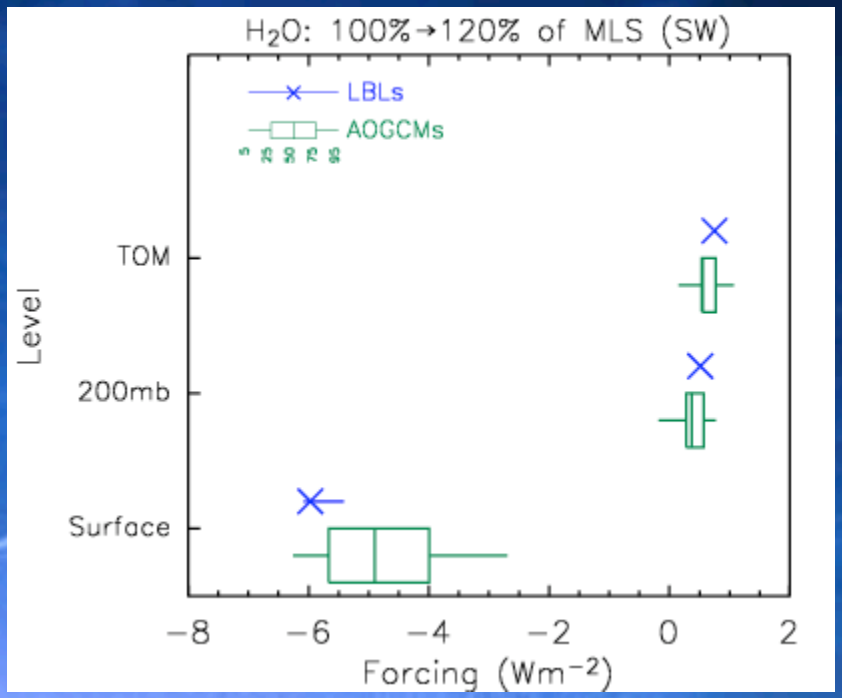

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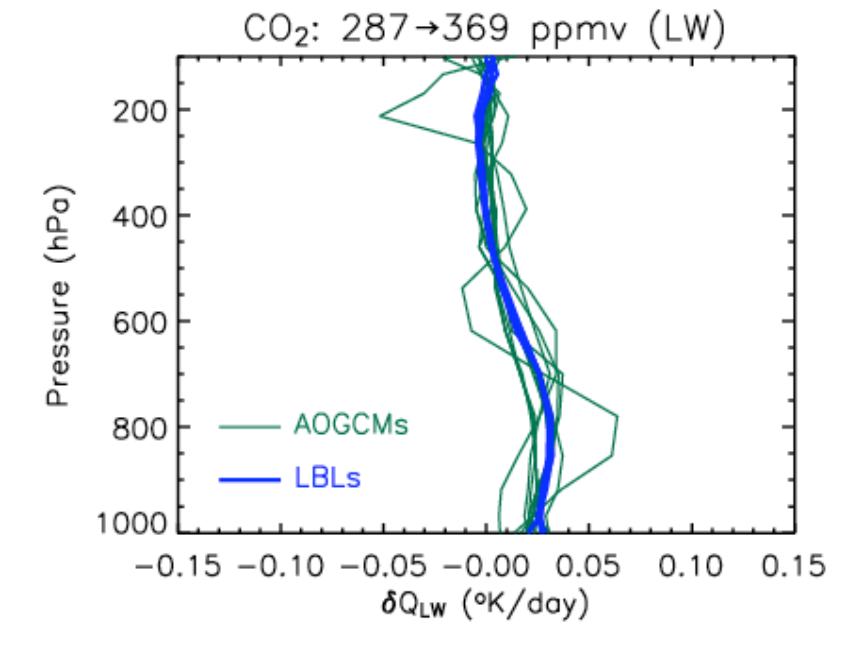
Change in heating rates by CO_2

Longwave



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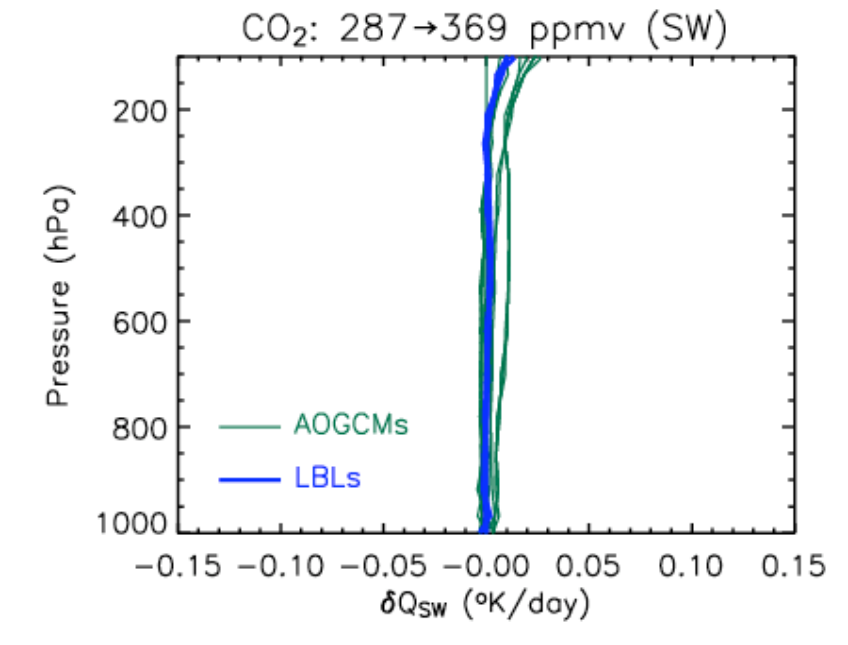
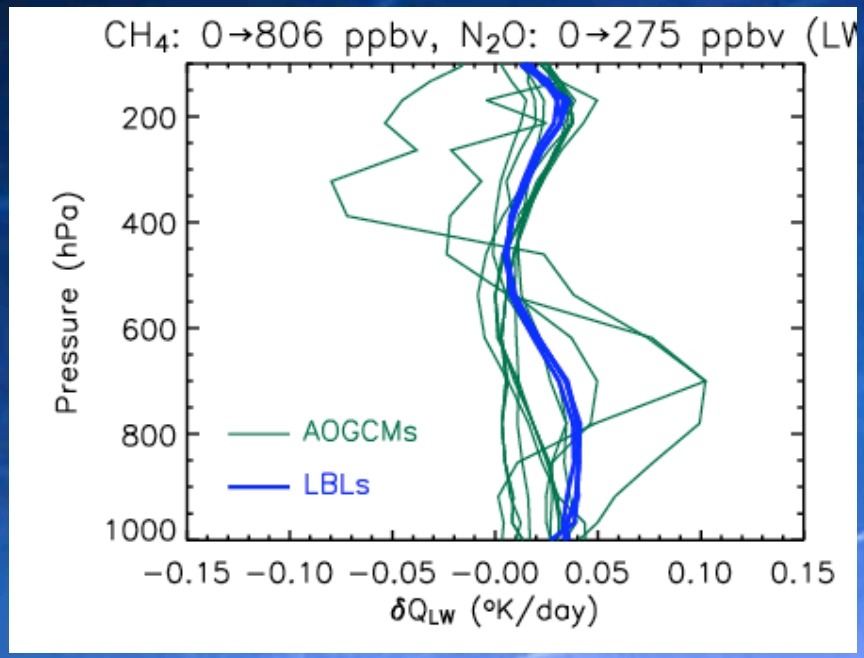


Collins et al, 2005

Change in heating rates by CH_4 and N_2O

Longwave



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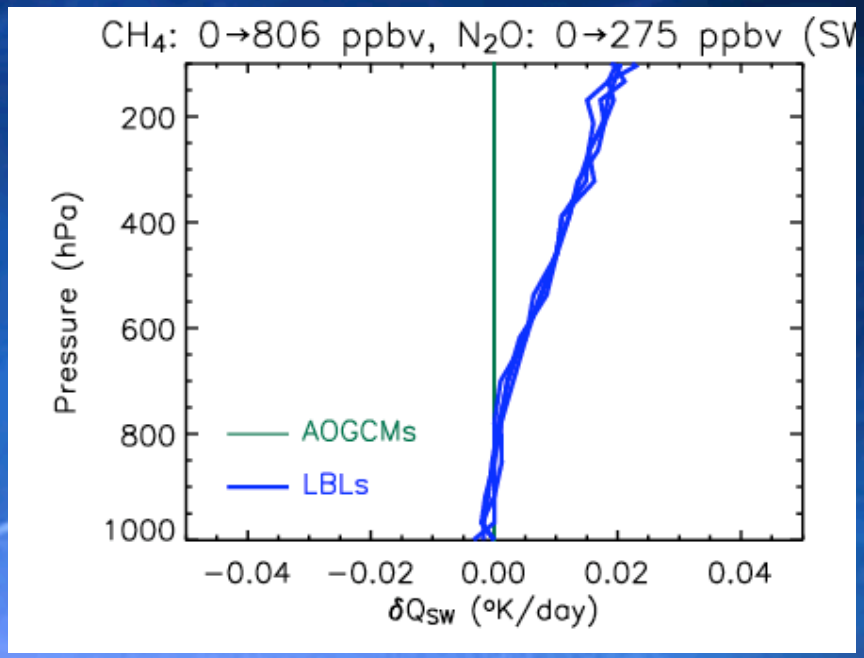
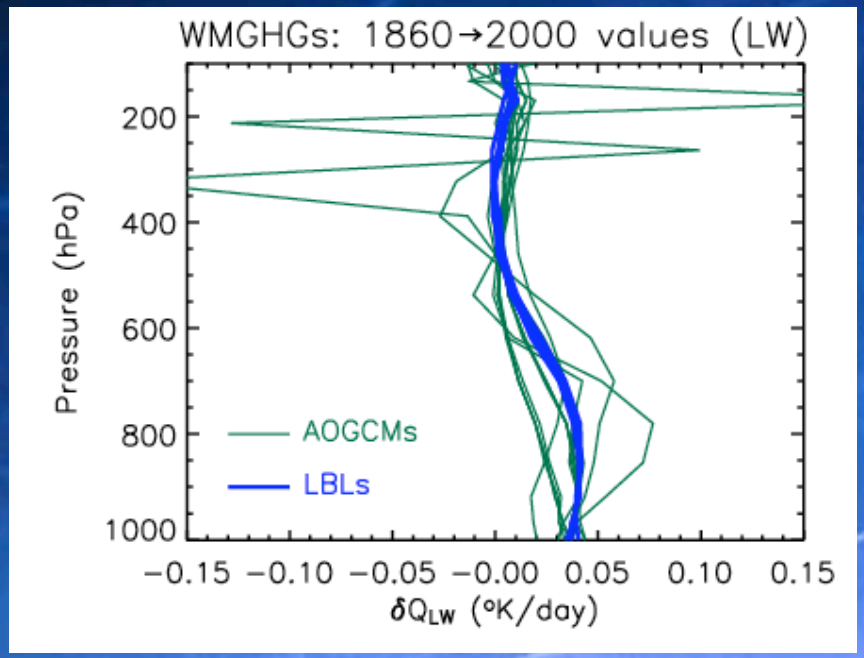


Collins et al, 2005

Change in heating rates by WMGHGs

Longwave



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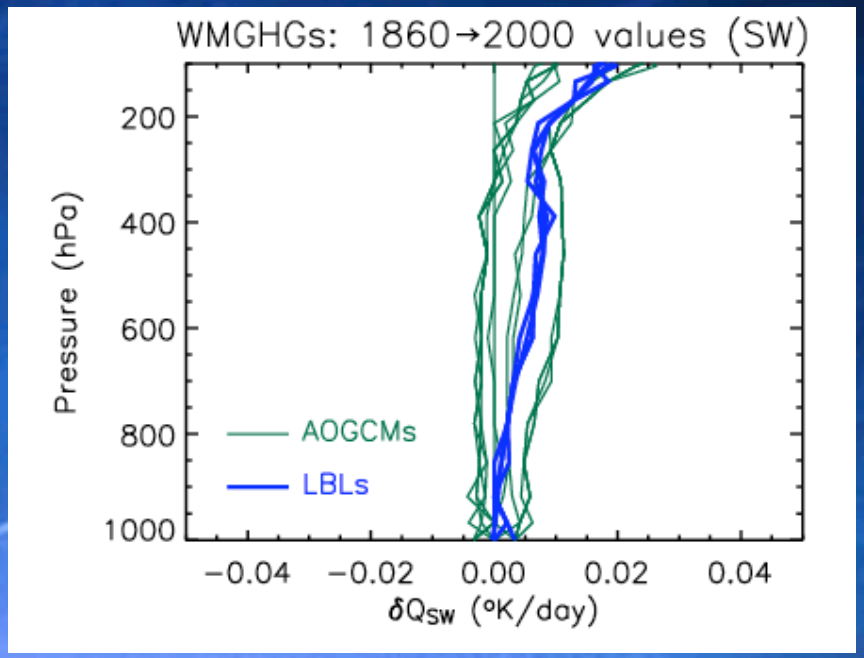
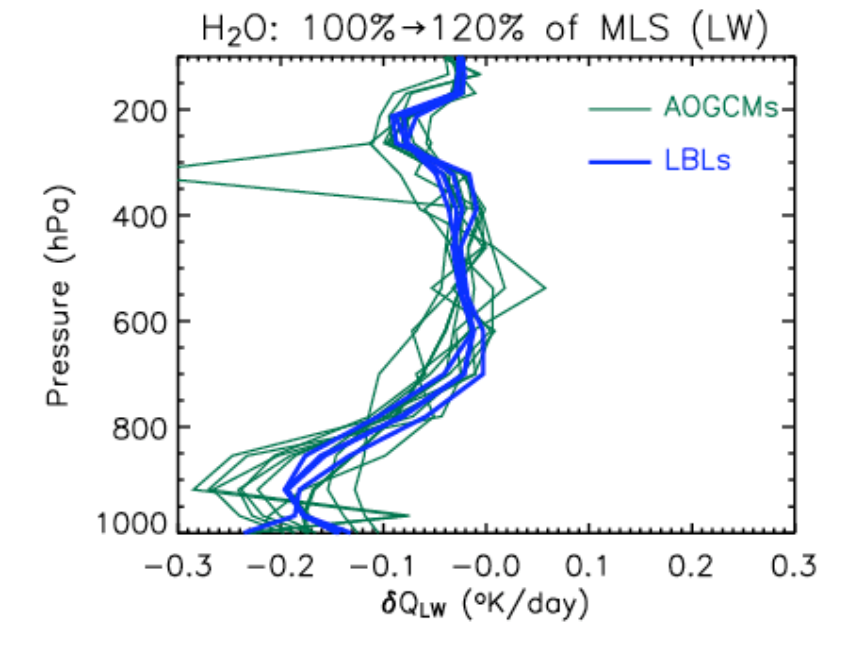


Collins et al, 2005

Change in heating rates by H_2O

Longwave



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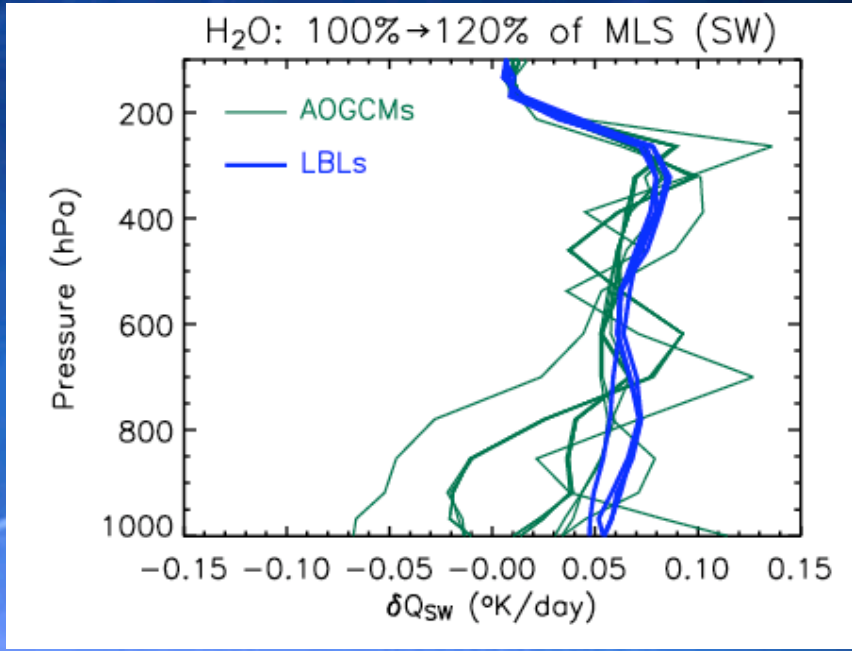
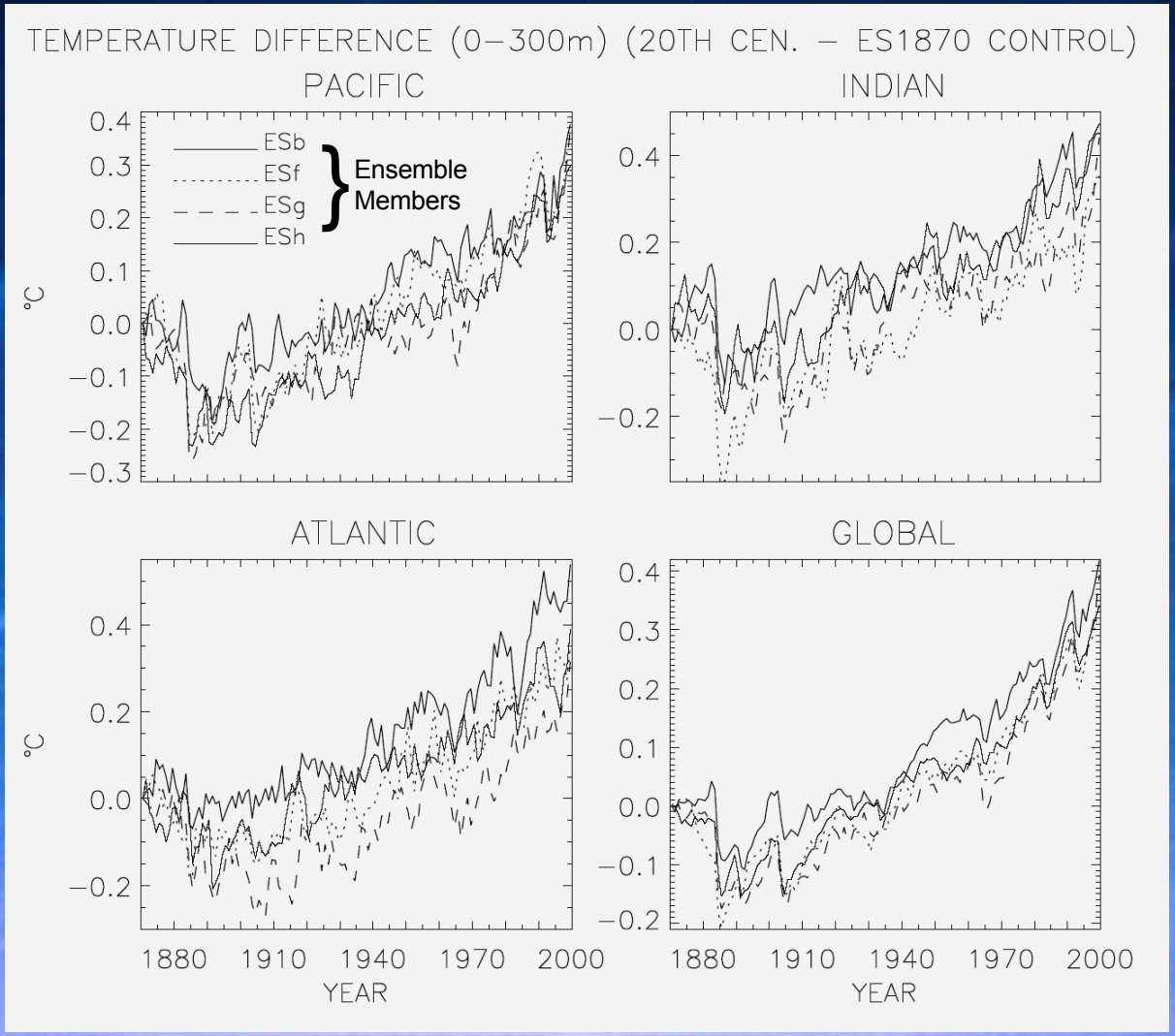


Collins et al, 2005

Trends in Ocean Temperature: Upper 300m

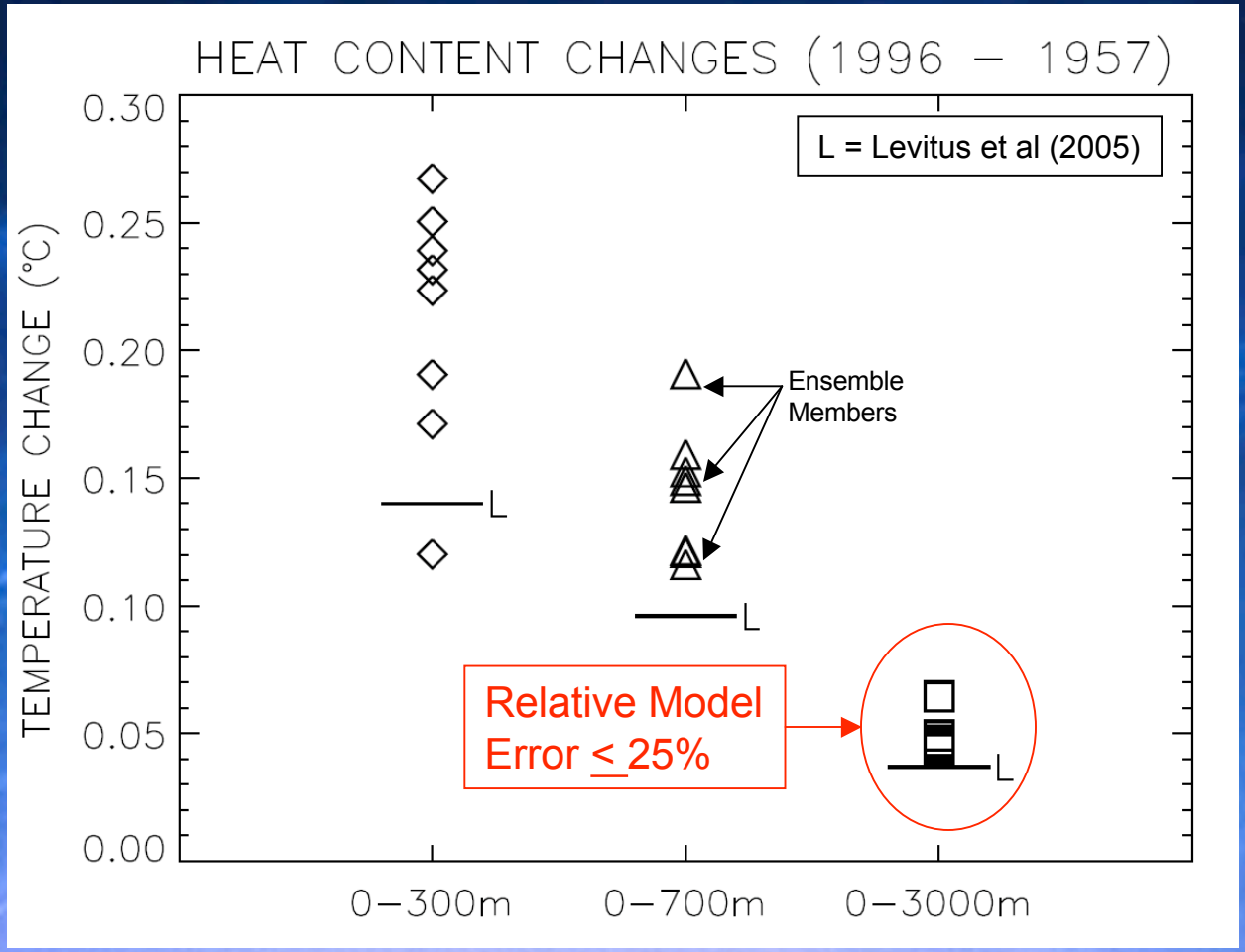
(Results from CCSM3 Ensemble)



Gent et al, 2005

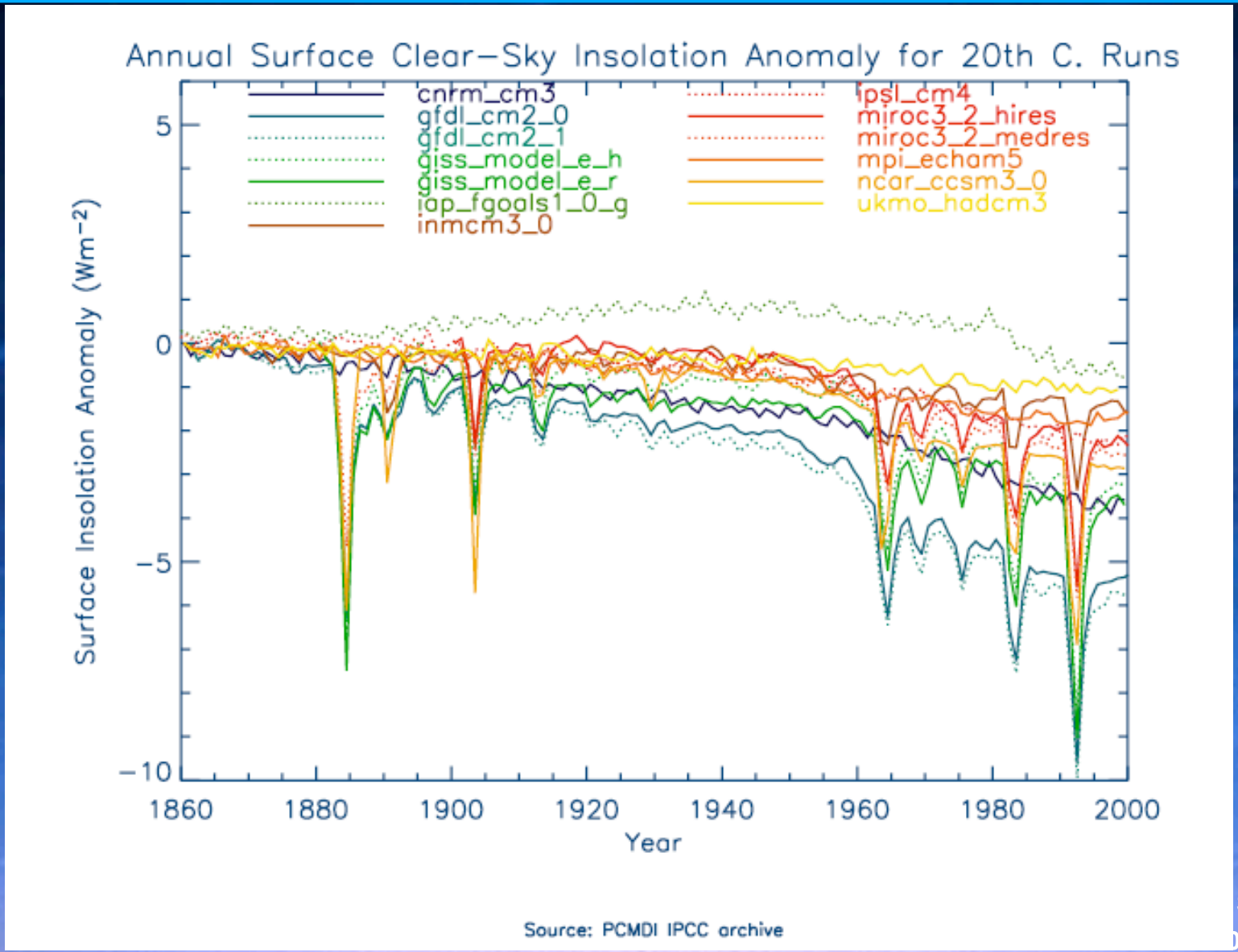
Increases in Global Ocean Temperatures

(Results from CCSM3 Ensemble)



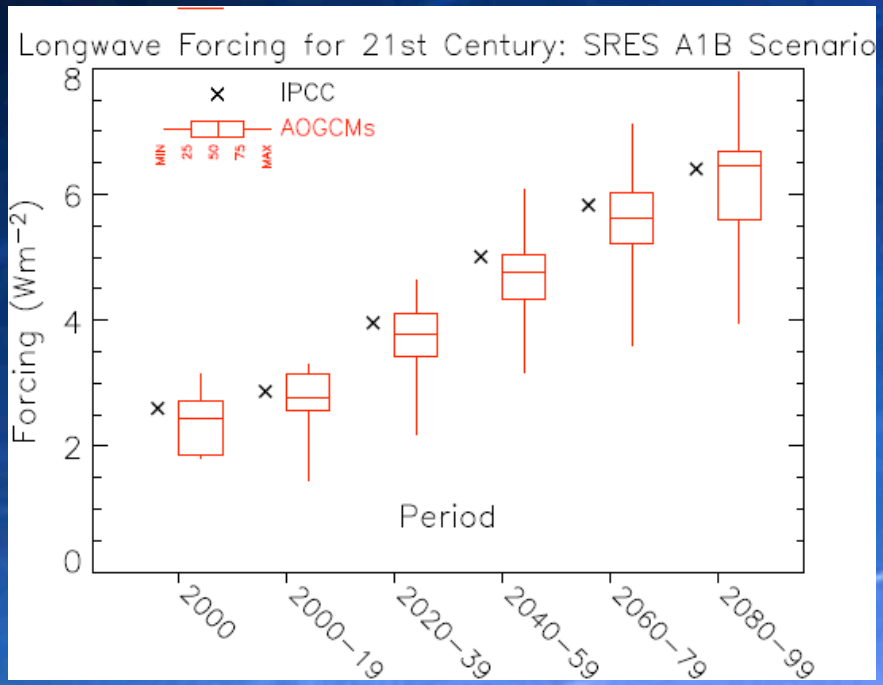
Gent et al, 2005

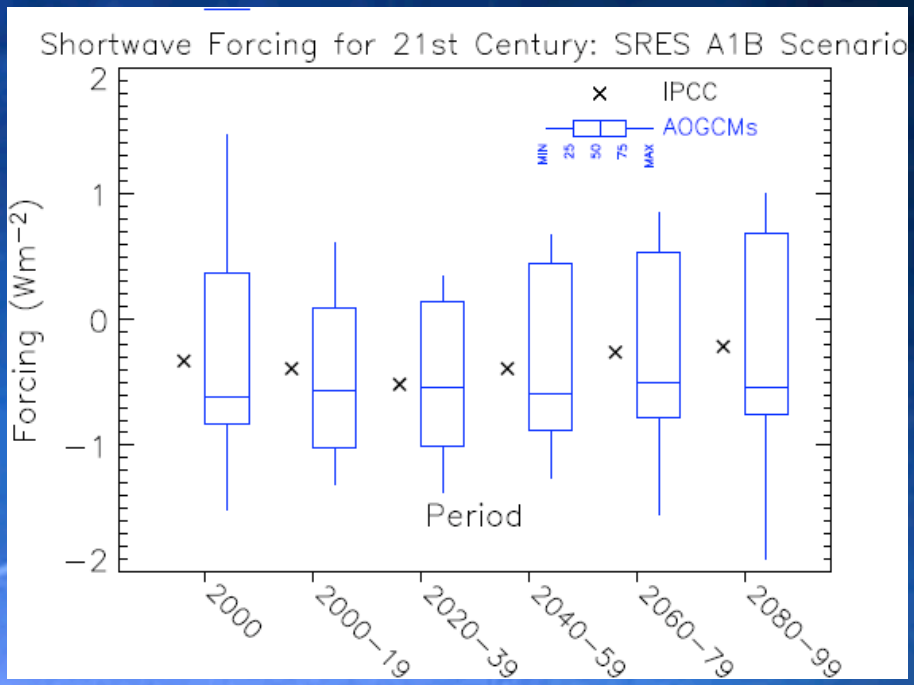
Change in Clear-Sky Insolation in IPCC Runs



Diagnosed forcings for AOGCM integrations

(SRES A1B scenario)





P.M.D. Forster, 2005

Conclusions

- No sign errors in the ensemble-mean forcings from AOGCMs!
  - Out of 228 individual forcing calculations, there is only sign error for one model.
- Forcing by historical changes in WMGHGs:
  - Mean LW forcings agree to within ±0.12 Wm^{-2}.
  - Individual LW forcings range from 1.5 to 2.7 Wm^{-2} at TOM.
  - This adversely affects separation of forcing from response.
  - Mean SW forcings differ by up to 0.37 Wm^{-2} (43% error).
  - Large SW errors are related to omission of CH_4 and N_2O.
- Largest forcing biases occur at the surface level:
  - Majority of the differences in mean forcings are significant.
  - AOGCM RT codes have been designed to produce reasonable forcings at the tropopause.
  - Developers also should insure accuracy of forcing at the surface.